UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 435

Contribution from the Bureau of Entomology.
L. O. HOWARD, Chief.

Washington, D. C. November 25, 1916

EXAMINED

THE APPLE LEAF-SEWER.

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INTRODUCTION.

In the summer of 1914, while engaged in deciduous-fruit insect investigations at Winchester, Va., the writer's attention was attracted by the common occurrence of the apple leaf-sewer, *Ancylis nubeculana* Clemens, sometimes termed the apple leaf-folder, upon apple foliage.

Although injury to apple foliage by the larva of this insect was recorded by Riley as early as 1877, very little concerning it has been published since. This apparent lack of attention may be attributed to the fact that although common and widely distributed, it has occurred so far only at infrequent intervals in sufficiently large numbers to cause serious damage and attract special notice to it, as an economic pest.

The feeding habits of the larva, while interesting when contrasted with those of other leaf-inhabiting species, are such as, under certain conditions, render the insect capable of considerable damage to the foliage of the apple, especially in young orchards receiving indifferent care. At the suggestion and under the direction of Dr. A. L. Quaintance, of the Bureau of Entomology, the study of the biology of this insect was made in the summer of 1914 and 1915.

NOTE.—This bulletin will be found of value to apple growers in the North and Central Atlantic States, the Middle West, and portions of Canada.

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HISTORY.

This species was first described by Clemens, in 1860, under the name of *Anchylopera nubeculana* Clem. In 1875 Zeller described the adult, pupa, and larva under the name of *Phoxopteris nubeculana*. The first record of injury caused by this species is given by Riley, who called it by the common name of "apple leaf-sewer," in his annual report of 1878, the injury occurring in Ontario County, N. Y., where certain orchards were seriously affected, one-fourth of the leaves being infested. In 1878 P. H. Hoy reported it a serious orchard pest in Wisconsin, while Lugger, in 1899, reported injury by this insect in Minnesota. The moth has also been recorded as abundant in Ontario (Canada) orchards in 1895 and 1903. Felt in 1907 recorded the ravages of the insect in New York State and gave measures for its control. Slingerland and Crosby have given a short account of the apple leaf sewer in their recent "Manual of Fruit Insects."

DISTRIBUTION.

Dyar gives the distribution of this species as "North Atlantic States." Fernald received it from Nova Scotia (Canada), while Rounthwaite collected it in Manitoba and Fletcher recorded it from Ontario. In the United States, specimens in the United States National Museum, the correspondence, notes, and collection of the Bureau of Entomology, and the available literature, all indicate that this species occurs in the following States: Connecticut, Illinois, Maine, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Virginia, and Wisconsin.

FEEDING HABITS AND CHARACTER OF INJURY.

This insect appears to confine its attack to the apple.

Immediately on leaving the egg the larva migrates to the vicinity of one of the prominent main ribs on the underside of the leaf and spins a sheltering web of silk, under which it begins to feed (fig. 1, *b*). The larva never feeds before completing its shelter of silk, and during the first 3 or 4 weeks of its life does not leave this silken covering, but extends it from time to time over the tender parenchymatous tissue on the underside of the leaf, gradually drawing the lower sides of the leaf together (fig. 2). At the end of this period, the young larva, having increased very materially in size, gnaws through the upper tissues of the leaf and makes its way to a fresh leaf, usually the one directly above. Here it stations itself on the upper side of the leaf at the juncture of the midrib and stem and spins another web of silk. Each strand crosses the midrib at right angles, and both ends of each strand are fastened

to the leaf at equal distances from the midrib. At the beginning, this web is about three-eighths of an inch in width and somewhat

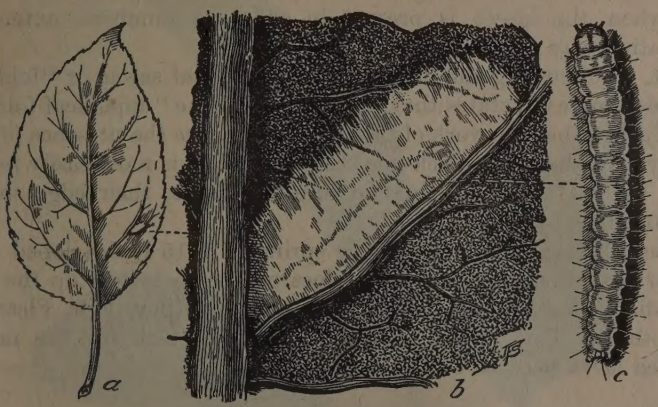

FIG. 1.—Apple leaf-sewer (*Ancylis nubeculana*): *a*, Apple leaf showing location of silken covering of newly hatched larva; *b*, portion of same, much enlarged; *c*, newly hatched larva, much enlarged. (Original.)

greater in length, but gradually the outer edges of the leaf are drawn together and at the end of 24 hours are completely joined (fig. 3, *a*).

FIG. 2.—The apple leaf-sewer: Work of young larva on leaf. (Original.)

In constructing this web and weaving the strands of silk from the sides over the midrib, the larva appears to exert no force, and the drawing together of the upper sides of the leaf probably results from contraction of the silken strands in drying.

When the leaf has been folded in this fashion, the larva sews the two halves securely together with silk immediately under the edges. Within this folded leaf (see Pl. I, fig. 1) the insect continues to eat the upper parenchyma, the excrement being deposited within the fold near the stem end (Pl. I, fig. 3). The leaf soon begins to present a scorched appearance and the larva eventually gnaws a hole through the

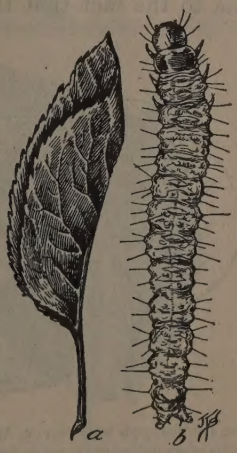

FIG. 3.—The apple leaf-sewer: *a*, Folded leaf showing how feeding larva is protected; *b*, full-grown larva, much enlarged. (Original.)

side (Pl. I, fig. 2) and, crawling to another leaf, repeats the folding and sewing operation.

During the season a single larva will thus destroy several leaves, and when the insect is present in sufficient numbers, extensive defoliation may result.

Felt, in discussing the habits of the apple leaf sewer or "folder," as he designates it, states that the common name "apple leaf folder" exactly describes the work of the caterpillar, since the presence of the dark yellowish-green, black-marked caterpillars is most easily recognized by the apposed halves of infested leaves, their edges being held together by strands of silk.

From observations made in the spring of 1915 it developed that the larva of the apple leaf-sewer does not begin to sew up the leaf immediately on leaving the egg, as stated by Riley, Felt, Fletcher, and others. This would seem an impossible task for the newly hatched larva because of its minute size.

DESCRIPTION OF STAGES.

THE EGG.

As far as can be ascertained, no description of the egg has been made in the literature of the apple leaf-sewer. This is probably due to the fact that the egg is minute, inconspicuous, and difficult to detect. Except in color, it bears a striking resemblance to the egg of the codling moth, being a flat, somewhat oval-shaped object with a raised circumference or flange and a shallow depression in the center (fig. 4, *b*). The eggs are about the size of pinheads, and are fairly uniform, averaging about 0.8 mm. in length and 0.6 mm. in width. The surface is covered with a network of ridges which are closer together and more regular toward the central portion than around the edges. When first deposited the eggs are the color of the leaf and it is only in reflected light that they can be detected. In 48 hours the color changes to a deep yellow. Later the embryo is indicated by the raised outer edge becoming darker in color, and shortly before hatching the larva is plainly visible, bent like a U around the central depression. The eggs are always securely glued

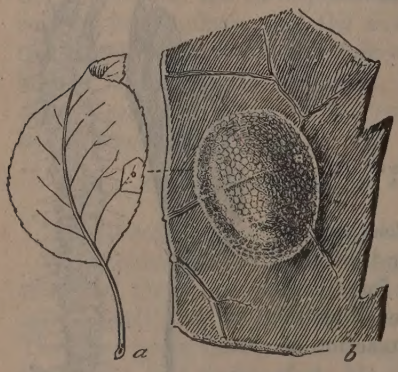

FIG. 4.—The apple leaf-sewer: *a*, Apple leaf, with position of egg indicated; *b*, egg on portion of leaf, greatly enlarged. (Original.)

THE APPLE LEAF-SEWER.

FIG. 1.—Twig bearing two leaves infested by the apple leaf-sewer (*Ancylis nubeculana*). FIG. 2.—Leaves killed by the apple leaf-sewer, showing exit holes of larvæ. FIG. 3.—Infested leaf torn apart, exposing larva, silken web, and partially destroyed parenchyma. (Original.)

to the leaf and are usually deposited on the under side, singly or in irregular groups (fig. 4, *a*). After hatching the eggshell is white and retains its shape. One often finds shells which remain for some time after the egg has hatched.

THE LARVA.

On hatching, the larva escapes through an irregular crack near the outer edge and leaves the eggshell in 2 or 3 minutes. The newly hatched larva is very active; its color is yellowish green throughout, with the exception of the orange-colored head. Riley describes the full-grown larva as follows:

Length about 11.5 mm. Head a yellowish orange, thoracic shield yellowish, the body a variable fuscous yellowish green. The head is somewhat flattened, the labium reddish brown, the mandibles fuscous apically and the small antennæ are whitish basally, pale orange near the middle, and semitransparent apically. The large thoracic shield has irregular black markings at the lateral posterior angles, the body is somewhat more fuscous laterally, and the setigerous tubercles are rather large, lighter than the body, and each bears a single fuscous hair. Anal plate yellowish with a conspicuous irregular, transverse, black spot on the posterior half. True legs with the basal segment fuscous yellowish, the other segments dark brown or black, prolegs pale yellowish green.

There is great variation in the size and color of the larvæ, but the conspicuous black spots near each outer hind corner of the thoracic shield serve as a ready means of identification (fig. 3, *b*).

THE PUPA.

When first formed, the color of the pupa is a dark yellowish brown (fig. 5, *b*). The last four abdominal segments retain their original color, but the head, eyes, and wing shields gradually change to black, mottled with yellow. The wing shields extend to the fourth abdominal segment; the antennæ not quite so far. The anterior and posterior borders of each abdominal segment are armed dorsally with a transverse row of minute decurved spines. The anal segment is quite sharp. The size is variable and averages 3 mm. by 7.5 mm.

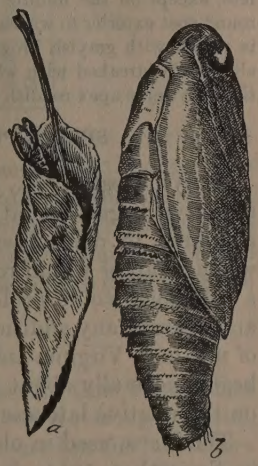

FIG. 5.—The apple leaf-sewer: *a*, Apple leaf showing pupal case and manner of emergence; *b*, pupa, much enlarged. (Original.)

THE ADULT.

The moth (fig. 6) measures about 18 mm. across the expanded wings. The head, thorax, and abdomen are dark brown dorsally and light gray upon the ventral side. The antennæ are dark brown,

while the legs are light gray. The fore wings are marked by heavy white areas near the anterior margin and with a broad, oblique white stripe on the posterior margin near the extremity. The hind wings are light gray, merging into a somewhat darker gray at the outer margins.

FIG. 6.—The apple leaf-sewer: *a*, Adult moth, much enlarged; *b*, same, natural size, at rest. (Original.)

The adult was first described by Clemens in 1860. The following is his description:

Anchylopera nubeculana n. s. Fore wings white, with a dark brown dorsal patch extending from the base to the middle of the wing, with its costal edge irregular or doubly curved. The oblique central fascia is almost obsolete, except on the middle of the costa, where it appears as a dark grayish brown round spot exterior to which is a short black dash. The wing above the inner angle is varied with grayish brown and brownish. The costa exterior of the middle is alternately streaked with white and brownish, becoming reddish brown toward the tip. Extreme apex reddish brown.

SPRING PUPATION OF WINTERING LARVÆ.

At Winchester, Va., in the spring of 1915, pupation of the wintering larvæ began the latter part of April, and from that time pupation appeared to depend entirely on the temperature. A few days of warm weather would result in several larvæ entering pupation, while a cold spell would prolong that period for those already in pupation and prevent any additional larvæ from transforming. In the latitude of northern Virginia and the District of Columbia pupation evidently begins normally about April 20, or possibly a little before, depending on the relative lateness of the season.

The larvæ used in obtaining these pupation records were collected in November, 1914, shortly before the leaves began to drop. They were placed in rearing jars partly filled with soil and carried through the winter in an out-of-doors rearing shelter. The beginning of pupation was readily observed, since the larva pupates within the folded leaf in which it undergoes the final molt.

TABLE I.—*Length of pupal period of wintering larvæ of the apple leaf-sewer, Winchester, Va., 1915.*

No. of observation.	Date of—		Length of pupal period.
	Pupation.	Emergence of moth.	
			Days.
1	Apr. 19	May 13	24
2	Apr. 21	...do	22
3	Apr. 22	May 15	23
4	May 4	May 26	22
5	...do	May 27	23
6	...do	May 28	24
7	...do	June 1	27
8	May 8	June 4	27
9	...do	June 6	29
10	...do	...do	29
11	...do	June 3	26
12	May 9	June 8	30
13	May 11	June 7	27
14	...do	...do	27
15	...do	June 8	28
16	...do	June 7	27
17	May 12	June 8	27
18	...do	...do	27
Max			30
Min			22
Av			26.05

The longest pupal period observed was 30 days, the shortest 22 days, and the average of the 18 observations 26.05 days. The records at Winchester show a much longer duration of this stage than has been observed by others, though data from other sources are rather limited. Johannsen, in 1909, states that in Maine the larvæ transform to chrysalids during April and that about 10 days later the moths begin to appear.

EMERGENCE OF MOTHS.

Table I gives the time of appearance of moths that emerged at Winchester in the spring of 1915 from field-collected rearing material, with the exception of the first adult, which appeared in the laboratory on May 7, and upon which no pupal record was obtained. The main emergence, however, did not begin until the latter part of May.

As before stated, pupation takes place within the folded leaf. When ready to emerge the pupa forces its body through the edges or some convenient crevice of the folded leaf until about half the body is projected. The moth then emerges, crawls about upon the dead leaf, and holds the wings over the head to dry, leaving the discarded pupal skin hanging through the leaf (fig. 5, *a*). The moths emerge during the early hours of the morning, several having been observed drying their wings at that time.

The moth is extremely difficult to detect in the orchard, but on three separate occasions, May 27, June 3, and June 6, adults were captured in the field, which verifies to some extent the emergence period observed in the laboratory.

OVIPOSITION OF THE MOTHS.

As the moths emerged from day to day they were transferred to rearing jars containing apple twigs in leaf, the ends of which were placed in small vials of water to maintain freshness. The eggs are laid singly or in irregular groups, usually on the underside of the leaf, but sometimes on the upper side, and are securely glued to the leaf; in fact, they can not be removed without crushing. In the rearing cages the eggs are often deposited indiscriminately upon the sides and bottom of the jars.

TABLE II.—*Oviposition of moths of apple leaf-sewer, Winchester, Va., 1915.*

Number of cage.	Number of moths.	Date of—			Days.		
		Emergence.	First oviposition.	Last oviposition.	Before oviposition.	Of oviposition.	From emergence to last oviposition.
1	3	June 1	June 2	June 7	1	6	7
2	4	June 6	June 7	June 11	1	5	6
3	3	June 7	June 9	June 19	2	11	13
4	4	June 8	...do....	June 21	1	13	14
Maximum					2	13	14
Minimum					1	5	6
Average					1.25	8.75	10

From Table II it will be seen that the moths begin to deposit eggs in from 1 to 2 days after emergence, the average for 4 observations being 1.25 days. The average period of oviposition lasted 8.75 days, the longest period observed being 13 days and the shortest 5 days.

While these observations show that the moths oviposit very shortly after emerging, Johannsen, in 1909, states that in Maine moths appear in April and deposit their eggs in June.

Copulation has not been noted, but occurs very soon after emergence, as indicated by the short period between emergence and oviposition.

No individual egg-laying records were obtained, but in confinement the moths averaged about 65 eggs each.

LENGTH OF LIFE OF MOTHS.

The length of life of 11 adults is given in Table III.

TABLE III.—*Length of life of moths of apple leaf-sewer, Winchester, Va., 1915.*

Number of moths.	Length of life.	Number of moths.	Length of life.
1	5	1	15
2	8	1	15
1	10	1	17
1	12	1	18
2	14		
Total		11	114
		Maximum	18
		Minimum	5
		Average	10.3

These moths were supplied with honey and water. Several moths were given no food or water and several were given water alone. The former lived only a few days after emergence and the latter lived a shorter period than those supplied with both water and honey.

The moths fed upon water and honey lived from 5 to 18 days, the average of 11 observations being 10.3 days. No data were obtained upon the relative longevity of the sexes.

HABITS OF MOTHS.

The moths are active during the day, especially in the morning, at which time they appear to deposit most of the eggs. In the rearing cages they are rather inactive, spending most of the time resting on the underside of the leaves, with their wings tightly folded (fig. 6, *b*). In the orchard they are active, making short, quick, erratic flights from one portion of the tree to another. The moths are so small and so adept at hiding that they are seldom observed in the orchard.

INCUBATION OF EGGS.

The shortest incubation period observed was 7 days, the longest 13 days, and the average for 16 lots of eggs 8.8 days. As a rule, the incubation period for the individual eggs of a given lot varied only a few hours, and in recording observations for any lot of eggs incubation was considered over when the first egg hatched. Table IV shows the incubation period of the eggs.

TABLE IV.—*Incubation period of eggs of apple leaf-sewer, Winchester, Va., 1915.*

Number of eggs observed.	Date—		Period of incubation.
	Deposited.	Hatched.	
			Days.
25	June 2	June 15	13
6	June 5	June 14	9
13	June 6	June 15	9
24	June 7	June 16	9
53	June 8	June 17	9
52	June 9	...do....	8
39	June 11	June 18	7
62	June 12	June 19	7
41	June 13	June 20	7
48	June 14	June 22	8
23	June 15	June 23	8
17	June 16	June 25	9
28	June 17	June 26	9
21	June 18	June 25	7
5	June 19	June 30	11
5	June 21	July 2	11
Average			8.8

LARVAL FEEDING PERIOD.

As fast as the larvæ hatched in the laboratory they were transferred to the leaves of young trees growing within cages of wire netting. When placed upon the leaf the newly hatched larva immediately crawled to the underside of the leaf and began the construction of its silken web, as previously described. About this time (June 24) young larvæ were very abundant in the young unsprayed orchards in the vicinity of Winchester, Va. During the remainder of the summer the larvæ continued to feed upon the leaves, the length of the feeding period therefore being directly dependent on the time the individual infested apple leaves begin to drop in the fall. The leaves infested by the apple leaf-sewer usually fall before the rest of the normal foliage, owing to their weakened condition. In 1914 the leaves continued upon the trees until about November 20, while in 1915 they had all fallen to the ground by November 6. Table V shows the feeding period of the larvæ.

TABLE V.—*Feeding period of the larvæ of the apple leaf-sewer, Winchester, Va., 1915.*

Number of individuals.	Date— Began feeding.	Leaf dropped.	Number of days feeding.
1	June 15	Nov. 3	141
1	June 16	Nov. 1	138
1	June 17	Oct. 30	135
1	June 18	Oct. 31	135
1	June 19	Nov. 6	140
1	June 20	Oct. 31	133
1	June 22	Nov. 5	136
2	June 23	...do....	135
2	June 25	Nov. 1	129
1	June 29	Nov. 2	129
1	June 30	...do....	125
2	July 2	Nov. 4	125
Total. 15			
	Av....	.....	132.66
	Max....	.....	141
	Min....	.....	125

The shortest feeding period was 125 days, the longest 141, while the average for 15 observations was 132.66 days. The leaves become dry and hard within 2 or 3 days after falling. The feeding period of the individual larva was therefore considered as completed when the leaf infested by it had fallen from the tree.

HIBERNATION.

When the folded leaf containing the larva falls to the ground in the late fall, the larva lines the inside of the folds with silk and hibernates until spring. Experiments indicate that the larvæ hibernating in the fallen leaves are able to withstand great extremes of moisture and temperature conditions, and that a larger proportion of them successfully withstand the winter than would ordinarily be supposed.

NATURAL ENEMIES.

The larvæ of *Ancylis nubeculana* are attacked by a number of parasitic and predacious enemies.

Pseudomphale ancylae Girault, n. sp. [MSS.], a hymenopterous parasite belonging to the family Chalcididae, was found to be a very common enemy of larvæ of the apple leaf-sewer in the vicinity of Winchester, Va. Six hundred and seventy-eight infested leaves were collected in the fall of 1914, and of these, 98 contained the pupal cases of this parasite, indicating that about 15 per cent of the leaf-sewer larvæ were destroyed. In late summer and early fall the parasitic larvæ leave the body of the host and spin their cocoons within the folded leaf, attaching the cocoons along the midrib of the leaf. From 4 to 6 parasites emerge from a single leaf-sewer larva. Only in two instances on examination at this time were pupæ found in these cocoons, and it appears that the parasite does not commonly overwinter within the folded leaf.

No parasites were reared from the breeding material in the spring of 1915.

Riley reared a braconid, *Rhysipolis phoxopteridis* Riley MS., from a leaf-sewer larva, in 1884, at Kirkwood, Mo., and in 1877, at Ithaca, N. Y., reared *Angitia paediscae* Riley MS.

Ants are an important factor in reducing the number of larvæ and pupæ during the winter and spring. In the spring of 1915, during the pupal period, ants almost ruined the writer's breeding material, which had been placed upon the ground under wire rearing cages.

REMEDIAL MEASURES.

The apple leaf-sewer larva migrates from one leaf to another several times during the season, which renders the control of this insect by the use of arsenical sprays very simple. According to the life-history studies of this insect at Winchester, Va., in 1915, the eggs begin to hatch about June 14 and continue hatching until about July 2, the maximum number of larvæ appearing about June 20. *The regulation arsenical spray of 2 pounds arsenate of lead to 50 gallons of water, applied by June 15, will therefore control this insect, and as the second spray for the first brood of codling moth is usually applied by the above date, in the vicinity of Winchester, no special application will be required for the control of the apple leaf-sewer.*

Spraying experiments conducted at Winchester, Va., indicate that even the full-grown larva is extremely sensitive to arsenical sprays and readily killed by that means. This is easily understood when one remembers that on sewing up the leaf the larva consumes all the upper parenchyma and can not escape the arsenate of lead deposited thereon by the spray.

In Virginia young apple trees which do not receive the arsenical spray are frequently defoliated by the apple leaf-sewer, whereas neighboring orchards in bearing, having received one or more codling-moth spray applications, almost entirely escape. Young orchards should receive the arsenical spray as soon as this pest appears in numbers sufficient to cause any serious damage.

Mr. Fred Johnson [1] describes conditions in Niagara County, N. Y., in 1905, as follows:

> The depredation of this pest is becoming quite marked in many orchards in the Youngstown district and also in orchards on the Canadian side of the Niagara River. The worst infestation coming under my notice is in an orchard of about 60 acres of the Greening, Baldwin, and Duchess of Oldenburg varieties.
>
> On many of these trees nearly all the leaves are sewn together and have a scorched appearance. The larva does not appear to attain its full growth in one leaf, but as soon as it has eaten the greater part of the tissue on the inside of the leaf which it has sewn together it gnaws a hole through the side of the leaf and escapes. It then attacks another leaf and proceeds as with the one it has vacated.
>
> This entire orchard is in sod and received only an indifferent spraying early in June. Parts of trees and whole trees that were fairly well sprayed have good foliage, whereas the foliage of trees or parts of trees which received little or no spray has either fallen or presents a scorched appearance on the tree.
>
> Duchess of Oldenburg trees sprayed June 9 and June 23 with 4 pounds of arsenate of lead to 50 gallons of full-strength Bordeaux mixture are quite free from this pest, whereas its ravages on the check trees are very marked. The condition of the foliage in this orchard at this date indicates that the pest can be held in check by thorough spraying at the dates that applications are usually made for scab and codling moth.

Mr. Johnson used 4 pounds of arsenate of lead to 50 gallons of water, but the spraying experiments conducted at Winchester, Va., indicate that 2 pounds of arsenate of lead to 50 gallons of water is sufficient for the control of the apple leaf-sewer. Lime-sulphur solutions or Bordeaux mixture may or may not be added, according to orchard conditions.

SUMMARY.

When present in sufficient numbers, the apple leaf-sewer may cause serious injury to apple foliage.

The apple leaf-sewer is generally distributed over the North and Central Atlantic States, the Middle West, and in portions of Canada.

The insect appears to confine its attack to the apple.

The newly-hatched larva spends the first 3 or 4 weeks of its life under a silken covering on the underside of the leaf. The remainder of the larval feeding period is passed within a succession of folded leaves. It destroys these leaves by eating the upper parenchyma.

In appearance the egg is very similar to that of the codling moth. The average period of incubation was found to be 8.8 days.

The full-grown larva is yellowish green, with an orange-colored head and thoracic shield, the latter with irregular black markings

[1] Unpublished notes, Bureau of Entomology.

at the lateral posterior angles. This last character serves as a ready means of identification.

The larval feeding period varies from 125 to 141 days.

The larva hibernates upon the ground within the fallen leaf, and while in this state is able to withstand wide extremes of moisture and temperature.

When first formed the pupa is a dark yellowish brown, some portions later changing to black, mottled with yellow.

The moth is grayish brown and measures about 18 mm. across the expanded wings.

In the latitude of northern Virginia, in a normal season, pupation begins about April 20, or possibly a little before, depending on the relative lateness of the season. The larva pupates within the folded leaf upon the ground. The average pupal period of the wintering larva of the apple leaf-sewer at Winchester, Va., in 1915, was 26.05 days.

In 1915, the moths continued to emerge from May 7 until June 8. They began to deposit eggs upon the apple foliage in from one to two days after emergence. Oviposition lasted from 5 to 13 days, and the moths averaged 65 eggs each. They lived from 5 to 18 days, averaging 10.3 days.

The moths are active during the day, especially during the morning, at which time they appear to deposit most of their eggs.

The principal insect enemy of the apple leaf-sewer in Virginia appears to be *Pseudomphale ancylae* Girault, n. sp. [MSS.], of the family Chalcididae.

At all times during the larval stage, the apple leaf-sewer is very susceptible to arsenical sprays. Arsenate of lead should be used at the rate of 2 pounds to 50 gallons of water. Bearing orchards receiving the customary spraying for the codling moth usually escape injury from the apple leaf-sewer. Young orchards should receive an arsenical spray as soon as the insect appears in numbers sufficient to cause serious damage.

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